<u>Venous Ultrasound I</u> Venous Insufficiency Ultrasound in Office Based Venous Procedures



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Disclosures

• I have no relevant financial disclosures.

Venous Disease

- Venous thromboembolism 4th leading cause of death in Western countries
- Chronic venous insufficiency affects 1/3 of the adult population in the US
- Venous ultrasound suspected deep vein thrombosis (DVT) the most common indication for duplex testing in hospitalized patients
- Venous ultrasound for insufficiency in the evaluation of limb edema & varicose veins becoming more common in outpatient settings

*Robertson et al. Epidemiology of chronic venous disease. Phlebology 2008;23:103-111. *van Bemmelen et al. Quantitative segmental evaluation of venous valvular reflux with duplex ultrasound scanning. J Vasc Surg 1989;10:425-431.

Overview

- Anatomy & Physiology of Venous System in Lower Extremity
- Duplex ultrasound for venous disease
 - Indications, preparation and performance
- Interpretation venous ultrasound for patency
- Interpretation venous ultrasound for reflux
- · Ultrasound for superficial venous procedures
 - Vein mapping
 - Procedural ultrasound
 - Post-procedural ultrasound

Venous Anatomy

- Lower extremity veins classified based on their relationship to the muscular fascia
- Deep veins
 - Beneath muscular fascia
 - Drain lower extremity muscles
- · Superficial veins
 - Above muscular fascia
 - Drain cutaneous microcirculation
- · Perforating veins
 - Penetrate the muscular fascia
 - Connect the deep & superficial veins



Size et al Inside Ultrasound Venous Vascular Reference Guide 2022

Inferior Vena Cava & Iliac Veins

- Inferior vena cava (IVC)
- Common iliac veins
- External iliac veins
- Internal iliac veins
- Pelvic veins
 - Left renal vein
 - Left and right gonadal veins
 - Trans and peri-uterine venous plexus



Deep Venous Anatomy

- Common femoral vein
- Deep femoral vein
- Femoral vein (formerly known as superficial femoral vein)
- · Popliteal vein
- Tibial veins (paired)
 - Anterior tibial veins
 - Posterior tibial veins
 - Peroneal veins
- Muscular sinuses
 - Gastrocnemius veins
 - Soleal veins



Mozes G, Gloviczki P. Vasc Endovasc Surg 2004;38:367-74.

Superficial Venous Anatomy

- Superficial veins in region between skin to the muscular fascia
- Great saphenous vein (GSV)
- Small saphenous vein (SSV)
- Anterior accessory saphenous vein (AASV)
- Intersaphenous vein



Mozes G, Gloviczki P. Vasc Endovasc Surg 2004;38:367-74.

Great Saphenous Vein

- Arises along the anterior aspect of the medial malleolus
- Ascends along the medial aspect of the calf and thigh
- GSV identified at the saphenofemoral junction joining the CFV
- Lies within fascial compartment



Bailly M. Cartographie CHIVA. Encyclope'die Me'dico-Chirurgicale. Paris, Elsevier, 1993, pp 43-161-B:1-4. Caggiati et al. Nomenclature of the veins of the lower limb. J Vasc Surg 2002:36:416-422.

Great Saphenous Vein

- Two main proximal valves of the GSV
 - The terminal valve
 - 1-2 mm distal to the SFJ
 - The preterminal valve
 - Approximately 2 cm distal to the SFJ
- Between these two values are key tributary veins of the GSV
 - Superficial circumflex iliac vein
 - Superficial epigastric vein
 - Superficial external pudendal vein



Meissner. Seminars Intervent Radiol 2005;22(3):147-156.

Small Saphenous Vein

- Arises at the lateral malleolus
- · Ascends along the posterior calf
- Terminates at the saphenopopliteal junction (SPJ)
- · Joins the popliteal vein
- Lies in a compartment between superficial & muscular fascia
- Similar to "eye" of the GSV



Garagozlo et al. Clinical Anatomy 2019;32:277-281.

Small Saphenous Vein

- SSV branch continues cephalad up posterior thigh
- Thigh extension of the SSV
- The location of the SPJ is notoriously variable
 - Junction may be within popliteal fossa or distal posterior thigh
 - 24.4% patients with no SPJ



Schweighofer et al. The anatomy of the small saphenous vein...J Vasc Surg 2010:51:982-989.

Anterior Accessory Saphenous Vein

- Origin from proximal GSV in most patients
- May share common origin with GSV at SFJ
- Prevalence of AASV reflux 10-14%
- Has same disease severity as refluxing GSV
- Lies anterior and parallel to the femoral vein
- Variable in length
- Typically has large tributary varicosities extending down the anterior and lateral aspect of the thigh & calf

Schul et al. J Vasc Surg Venous Lymphat Disord 2020:8:1014-1020.



Intersaphenous Vein

- Medial thigh anastomosis b/t the GSV and SSV
- Formed by:
 - Thigh extension of the SSV caudally*
 - Posterior accessory saphenous vein cranially
- Variable anatomy
- Formerly known as the Vein of Giacomini



Perforator Veins

- Veins connect the deep and superficial venous systems of the lower limb
- Historically named using eponyms
- Move toward use of topography for perforator veins
- Universally more translatable, descriptive
- Anatomic part of leg (foot, ankle, leg, thigh)
- · Exact location (medial/lateral/dorsal)



Caggiati et al. J Vasc Surg 2005;41:719-724

Venous Physiology

- Veins of the lower extremity
 - Thin-walled
 - High capacitance
- Venous return to the heart is dependent upon:
 - Effective pumping mechanism
 - Pressure gradient
 - Functional valves



Venous Physiology

- · Numerous small muscles of the foot contract
- Compress the plantar venous plexus serves to prime the calf muscle pump
- Contraction of the calf muscle is primary pump
 - Gastrocnemius and soleal muscles
 - Increased pressure up to 250 mmHg*
 - Relaxation, resting venous pressure falls to 15-30 mmHg
- · Unidirectional venous valves prevent retrograde flow
- Thigh muscles contribute less

Eberhardt /Raffetto Circulation 2005;111:2398-2409.

Calf muscle pump EF 65% Thigh muscle pump EF 15%

The Valves

- Bicuspid valves
 - Endothelial folds w connective tissue
- Most numerous in lower leg
- Decrease in number more proximally
- Function
 - Divide hydrostatic column of blood into segments
 - Flow from superficial to deep system
 - Flow from caudal to cephalad



Image courtesy of Donna Kelly, RVT, RPhS, RDMS Size et al Inside Ultrasound Venous Vascular Reference Guide 2022

Venous Pathophysiology

- Valvular incompetence leads to venous hypertension
- Resultant signs and symptoms consistent with chronic venous insufficiency
 - Varicose veins
 - Aching, heaviness, fatigue
 - Swelling of legs
 - Dermatitis
 - Venous ulceration



History of Duplex Ultrasound in Evaluation of DVT

- Prior to adequate imaging, diagnosis of DVT made by physical examination
- Homans' sign -
 - Pain with forceful dorsiflexion of the foot
- Clinical diagnosis was correct only 50% of the time!
- Phlebography introduced



Barshes/Belkin. Ann Surg 2015;261(2):416-420.

Diagnosis of Venous Insufficiency

- Historically phlebography was "gold standard" for evaluation of venous disease
- Ascending phlebography to evaluate DVT
- Descending phlebography to evaluate reflux
- Disadvantages
 - Invasive
 - Required use of fluoroscopy/not portable
 - Expensive
 - Painful
 - Associated with complications
 - Potential to induce chemical phlebitis

Kistner/Kamida. Dermatol Surg 1995;21:71-76.





Descending phlebography Reflux of contrast

Duplex Ultrasound

- Evolved as a non-invasive method of assessing LE veins for patency and valvular incompetence
- Used routinely since early 1980s
- Advantages
 - Non-invasive
 - Portability
- Reproducible

- Lower cost

- Safe for use
- Duplex ultrasound has ability to evaluate veins with:
 - B-mode imaging
 - Color Doppler
 - Pulsed wave Doppler spectral analysis



5 Characteristics of Normal Venous Blood Flow

- Spontaneous
 - Flow is present without augmentation
- Non-pulsatile
 - Flow accelerates and decelerates in response to respiration
- Phasic
 - Normal flow pattern varies in response to inspiration & expiration
- Augmentable
 - Flow velocity increases with distal limb compression
 - Confirms patency veins between transducer and site of compression
- Compressible
 - Collapse of veins with transducer compression signifies patent vein

Multifrequency Linear Array Probe

- Most common probes used for peripheral venous vascular examinations
- Transducer frequency
 - Superficial veins imaged with higher (6-15 MHz) linear-array transducers
 - Deep veins imaged with lower (2-9 MHz) transducers



Venous Duplex Ultrasound

Evaluate patency and reflux in the deep and superficial veins of the lower extremity

<u>Two distinct studies</u> Patency Study Duplex evaluation of deep and superficial vein patency Reflux Study Duplex evaluation of deep and superficial vein insufficiency

Indications for Duplex Ultrasound: Patency Study

- Swelling
- Limb pain or calf tenderness
- Pulmonary embolism to establish a source of embolus
- · Palpable cord
- Follow-up after venous intervention
 - Thrombolysis
 - Angioplasty and stent placement
 - Endovenous ablation procedure
- Evaluation of patency is always included in venous ultrasound for reflux



Patient Positioning

- Lower limb venous testing for patency
 - Semi-Fowler's position
 - Head elevated 30 degrees



Image courtesy of Donna Kelly, RVT, RPhS, RDMS

*Labropoulos J Vasc Surg 2003 **Carty et al. J Vasc Ultrasound 2013

Venous Duplex US for Patency

- Transverse grayscale images with and without transducer compression
 - CFV
 - SFJ
 - Deep femoral
 - Proximal, mid, and distal FV*
 - Popliteal vein
 - Posterior tibial veins (paired)
 - Peroneal veins (paired)
 - Gastrocnemius and soleal veins, if symptomatic posterior calf
- Veins examined in 3- to 5-cm intervals
- Complete coaptation to exclude the presence of thrombus at each location

*Femoral vein was previously called superficial femoral vein, Gloviczki et aled Vasc Surg 2011;53:2Se48Ss a deep vein



**Anterior tibial veins are not typically scanned due to a low incidence of thrombosis 0-0.3%* *Labropoulos et al. J Vasc Surg 1999;30:787-791

Venous Duplex US for Patency

- Spectral Doppler waveform
 - CFV at rest
 - Response to respiration
 - Spontaneity
 - Flow
 - Augmentation
- Visualization of blood flow throughout the entire lumen on color flow Doppler imaging



Phasicity: Indicator of Proximal Venous Obstruction

- Normal venous flow is phasic, varying with respiration
- Lack of respiratory variation in venous flow
 - Suspicious for proximal venous obstruction
- Comparison of left and right common femoral veins offer insight into proximal venous obstruction
 - Asymmetry in flow velocity b/t right and left CFV



Proximal Iliac Venous Obstruction

- Monophasic waveform in CFV
- 100% patients proximal DVT (22%) or extrinsic compression (78%)*
- Sensitivity 38.1%
- Negative predictive value 55.8%
- Specificity 100% Positive predictive value 100%



*Bach/Hann AJR 1997

Abdominal/Pelvic Imaging

- CFDU
 - Appropriate body habitus necessary
 - Fasting state to avoid increase in bowel gas
 - IVC, iliac venous system
- Axial imaging abdomen/pelvis
 - MR venogram
 - CT venogram
- Venography +/- IVUS



Left common iliac vein compression

Duplex US Characteristics in Acute vs. Chronic DVT



Superficial Vein Thrombosis

- Defined as thrombus within one of the axial superficial veins
- Concern is for propagation of the thrombus into the deep venous system
 - May occur via SFJ, SPJ, or less commonly via perforating veins
- Risk of concurrent DVT at time of SVT
 24.9% (210/844) DVT at diagnosis*
- Increased risk of future DVT, PE, recurrent SVT

Thrombosed AASV & associated tributary varicose veins



Superficial Vein Thrombosis

- Symptoms, erythema or tenderness, localized over superficial veins
- Images over symptomatic areas
 - GSV, SSV, AASV
 - AASV had a higher incidence of SVT than GSV
- When identified, documentation
 - Name involved superficial vein
 - Tributary involvement with location
 - Thrombus length
 - Thrombus distance from the SFJ/SPJ or perforating veins





Superficial Vein Thrombosis

- Treatment varies depending on duplex ultrasound findings
- · Axial superficial vein or tributaries
- · Tributary vv only treated conservatively
- · Involvement of axial superficial veins
 - Length of thrombus within the axial veins
 - Greater than 5 cm in length
 - Prophylactic doses anticoagulation 45 days
 - Increased risk with thrombus in <3 cm from deep veins
 - Treated as DVT
 - · Therapeutic doses anticoagulation 3 months

Decousus et al. NEJM 2010;363:1222-1232 Beyer-Westendorf et al. Lancet Haematol 2017;4(3):e105-e113.

Indications for Duplex Ultrasound: Reflux

- Signs of chronic venous insufficiency
 - Varicose veins
 - Chronic limb swelling
 - Stasis dermatitis
 - Venous ulcers
- Evaluation of deep and superficial veins for reflux
- Includes evaluation of deep and superficial veins for patency
- Also includes vein mapping with diameters
- Used to select patient for endovenous ablation procedures & to determine etiology of swelling/dermatitis



Patient Positioning

- Testing for venous insufficiency
 - Patency study is performed first
 - If positive for DVT/SVT, terminate study
 - Reflux study
 - Standing position
 - Elicits reflux by challenging venous valves & maximally dilating veins
 - Increases sensitivity & specificity in detecting pathologic reflux*
 - · Limb being imaged not bearing any weight





Sonographer Ergonomics



- · Ergonomic tools for sonographer
 - Height-adjustable table, US, stool
 - Step or platform to elevate patient
 - Automated rapid inflation cuff

Images courtesy of Donna Kelly, RVT, RPhS, RDMS

Eliciting Reflux

- Reflux may be elicited by
 - Compression and release of limb distal to point of examination
 - Automated rapid inflation cuff
 Offers standardization*
 - Manual compression calf or foot
 - Increased intra-abdominal pressure via Valsalva maneuver
 - Only used for proximal veins: CFV, SFJ
 - Requires patient teaching & cooperation
 - May elicit false negative results
 Especially w competent proximal valve



Transverse grayscale image with & without transducer compression

Documentation of Patency

- CFV
- SFJ
- GSV
- Proximal, mid, distal FV
- Popliteal vein
- Posterior tibial veins
- Peroneal veins
- SSV, AASV
- Intersaphenous vein, if present
- Scan along entire vein
 - Compress at 3-5 cm intervals



Non-compression

Compression

Spectral Doppler Waveforms at CFV

- At rest, normal breathing
- Phasic and symmetric

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Images courtesy	y of Donna Kelly, RVT, RPhS, RI	DMS						ľ

Documentation for Reflux

- Spectral Doppler Waveforms/Color Doppler
 - CFV
 - SFJ
 - FV
 - Popliteal vein
 - SPJ
 - Proximal, mid, distal thigh, & proximal calf GSV
 - Proximal and mid SSV
 - Proximal and mid AASV
 - Proximal and mid intersaphenous vein, if identified
 - Large perforating veins
- Extremity in dependent position
- · Response to distal augmentation
- · Measure duration of retrograde flow w calipers



Criteria for Venous Reflux

- Rapid inflation of cuff (velocity greater than 30 mmHg)
- · Antegrade flow of blood
- Release or rapid deflation of cuff
- Retrograde flow of blood

Diagnostic Criteria for Venous Reflux	
Deep venous system CFV, FV, PopV	>1000ms
Deep femoral vein, tibial veins	>500 ms
Superficial venous system	>500 ms
Perforating venous system	>500 ms



Reflux Duration and Severity of Disease?

- The duration of reflux does not correlate with the severity of venous insufficiency
- Neglan & colleagues* duration of valve reflux good qualitative marker for CVI, not to quantify severity of disease
- Data to suggest peak reflux velocity may be more accurate assessment of severity



Neglen et al. J Vasc Surg 2004. Pichot et al. J Vasc Surg 2004.

Documentation for Reflux

- Diameter measurements (transverse grayscale images)
 - SFJ
 - Proximal, mid, distal thigh, & proximal calf GSV
 - SPJ
 - Proximal & mid SSV
 - Proximal & mid AASV
 - Proximal & mid intersaphenous vein, if identified
 - Perforating veins, if incompetent, measured at the level of the fascia
- Documented with the extremity in a dependent position
- · Used in planning endovenous procedures



Helpful Details

- Helpful to note on pre-procedural US
 - Depth of vein from skin when obtaining diameter measurements
 - Length of AASV
 - Webbing or synechiae within vein
 - Anatomic abnormalities
 - Absent SPJ
 - Aneurysmal segments
 - Tracing varicosities back to their origin
 - Descriptors helpful tortuous, out of fascia



US Complexities Following Venous Procedures

- Following surgical ligation and stripping or endovenous ablation procedures, US documentation may be more complex
- Documentation of distance from the SFJ/SPJ to the closure
- Areas of recanalization of superficial veins with diameters/lengths
- Areas of neovascularization



Perforating Veins

- In patients with CVI, duplex scanning of perforating veins is performed selectively
- Patients with dermatitis & ulceration
- Definition of pathologic perforating vein*
 - Outward flow duration of >=500 ms
 - Diameter of >=3.5 mm measured at the level of the fascia
 - Location beneath a healed or open venous ulceration



Gloviczki et al. J Vasc Surg.2011

Venous US for Endovenous Ablation Procedures

- Use of ultrasound is a key element of endovenous ablation procedures
- Vein mapping prior to procedure
- · Confirmation of diameters and depths of target vein
- Cannulation of vein
- Placement & positioning of catheter
- Confirmation of vein closure
- Post-procedure identification of EHIT



Pre-Procedure Vein Mapping

- Formally by sonographer before procedure or by physician at beginning of procedure
- Measurement of diameters along length
 of the vein
- Marking over vein for ease of identification during procedure & for administration of tumescent anesthesia



Cannulation of the Vein

- Longitudinal or transverse views of the vein for cannulation
- Ultrasound probe in left hand with needle in right hand
- Sheath placement
- Ultrasound helpful to identify tortuous vein segments or large perforating veins in thigh which may affect catheter advancement
- Introduction and advancement of ablation catheter or fiber



Confirmation of Catheter Tip

- Identification of location of catheter tip
 - GSV or AASV Saphenofemoral junction
 - Catheter placement distal to superficial epigastric vein
 - SSV Saphenopopliteal junction
 - Catheter placement is typically at fascial curve
 - Identify gastrocnemius veins which join SSV



Administration of Tumescent Anesthesia



 Deliver tumescent anesthesia directly into the saphenous sheath with ultrasound guidance



Administration of Tumescent Anesthesia

 Transverse imaging to assure adequate tumescent anesthesia within saphenous sheath



Following Vein Ablation

- Confirmation of patency of deep veins and closure of treated superficial vein
- Post-procedure ultrasound at 48-72 hours
 - Confirm patency deep veins
 - Confirm closure of target superficial vein
 - Document distance of closure from junction w deep veins



Endothermal Heat Induced Thrombosis (EHIT)

- · Endothermal heat induced thrombosis (EHIT)
 - Propagation of thrombus from the ablated superficial vein into the deep vein
 - Incidence up to 3% after thermal ablation procedures
 - Most asymptomatic
- Distinct sonographic appearance
- Behaves like a stable thrombus
- Often regresses spontaneously after a few weeks of observation or short course anticoaguation

EHIT Classification

Class	Definition
1	Thrombus extended up to and including the deep vein junction
11.]	Thrombus propagation into the adjacent deep vein but comprising <50% of the deep vein lumen
111	Thrombus propagation into the adjacent deep vein but comprising >50% of the deep vein lumen
IV	Occlusive deep vein thrombus contiguous with the treated superficial vein



Kabnick et al. J Vasc Surg VLD. 2021;9:6-22.

Conclusions

- Venous disease is a common clinical entity
- Venous ultrasound is a wonderful non-invasive tool to evaluate for both patency and reflux
- Endovenous ablation procedures rely upon information obtained by ultrasound before, during, and after the procedure for success

